

The University of Chicago

LOSSES OF VITAMIN C DURING THE COOKING OF CERTAIN VEGETABLES

A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE BIOLOGICAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF DOCTOR
OF PHILOSOPHY

DEPARTMENT OF HOME ECONOMICS AND
HOUSEHOLD ADMINISTRATION

1938

By
FAITH FENTON

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The writer is greatly indebted to Dr. D. K. Tressler, Chief of the Chemistry Division, State Experiment Station, Geneva, New York, not only for helpful suggestions and direction throughout the progress of the work, but also for unfailing inspiration and sound training during the progress of the research.

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LOSSES OF VITAMIN C DURING THE COOKING OF PEAS

Certain well-known investigators have reported that open-kettle cooking of vegetables is very destructive to vitamin C. Eddy, Kohman and Carlsson ('26) found 2 gm. daily of ungraded raw market peas, and 5 gm. but not 3 gm. of these ungraded peas cooked, protective against scurvy in guinea pigs. This gives a loss of approximately 75% of vitamin C during cooking. Bessey and King ('33) report, by dye titration, 0.16 mg. of vitamin C per milligram of fresh peas and 0.06 mg. per gram of cooked peas. McHenry and Graham ('35) found 0.14 mg. per gram of raw peas and 0.08 mg. per gram of cooked peas or a cooking loss of 43%. Fellers ('35) lists peas in a group of vegetables losing 40 to 80% of their vitamin C "during a short cooking period." He reports 3.6 gm. of cooked peas as the protective level. Recalculated, on a basis assuming 0.5 mg. of ascorbic acid per day are required to protect a guinea pig from scurvy, this is 0.14 mg. of vitamin C per gram of cooked peas. He gives no data on the raw pea content.

In the studies on peas published previously, no consideration has been given to the cooking water, perhaps partly because it is difficult to get animals to eat the large amount of cooking water produced. The new chemical method offers a very simple means of determining the amount of ascorbic acid that goes into the water. Our purpose was to determine not only the ascorbic acid retained in the peas, but also that retained in the cooking water. From the standpoint of human nutrition, the results of animal feeding experiments do not give as exact information as do the chemical determinations, inasmuch as human beings commonly eat food before it is cooled.

In this study it was possible to control the variety, maturity, and freshness of the peas, as well as the method of cooking. The main object was to measure the relative amounts of vitamin C in the peas and in the cooking water at the 'done' stage and at various intermediate stages, as well as losses during the standing of cooked peas. Every effort was made to control all of the factors in such a way as to cause minimum loss of vitamin C with the exception that the aim in cooking was to make the cooked vegetable look attractive and taste well, with the loss of nutrients a secondary consideration.

EXPERIMENTAL

1. *Losses of vitamin C during the cooking of peas.* Two varieties of peas, Thomas Laxton and Alderman, were grown on upland soil (Ontario clay loam at Geneva, New York). They were hand-picked when they reached the succulent stage, hand-shelled, cooked, samples extracted, and titrated in as short a time as possible.

The method of cooking was essentially that of Halliday and Noble ('33), with the exception that 525 gm. (six servings) of peas instead of 350 gm. were used with the 700 cc. water and $\frac{3}{4}$ teaspoonful salt. A 3-quart enamel pan with an inside diameter of 7 inches was used. The peas were dropped into the rapidly boiling water and the time counted from the time the water came back to the boil (this took 2 minutes). The tap water (pH approximately 7.5) was boiled several minutes before the peas were added.

An arbitrary stage of 'doneness' for each variety was determined in advance by several judges, using the common household methods of testing with a fork and 'biting.' The boiling time for the Thomas Laxton and the Alderman varieties was 14 and 13 minutes respectively. Samples of the peas and of the cooking water were removed at intervals from the beginning of cooking to the 'overdone' stage. Samples were also taken at the 'done' stage from normal cookings in which there had been no interference from previous sampling.

The method of extraction, of standardization of the dye, and titration were essentially those of Bessey and King ('33). Trichloroacetic acid¹ was found to give a clearer extract of peas than acetic acid. Blanks were run with each dye used.

The samples of peas containing approximately 20 gm. were placed immediately into weighing bottles containing 25 cc. of 8% trichloroacetic acid. The weighing bottles containing the acid had been previously placed in an ice-salt mixture so that when the hot peas were added to the chilled acid, the whole was brought to room temperature in a very short time.

Immediately after removal of each sample for vitamin C determinations, samples were removed for moisture determinations so that the vitamin content was calculated on both the wet and the dry weight.

The cooking water in 25 cc. amounts was pipetted into 25 cc. chilled trichloroacetic acid in 50 cc. volumetric flasks.

There was little change of acidity, which might affect vitamin C stability, during the cooking. The total range of pH of the raw and cooked peas was from 6.30 to 6.88, indicating the presence of considerable buffer material in peas. The pH of the tap water used in cooking and of the cooking water at the 'done' stage was approximately 7.5 and 6.5 respectively.

For purposes of comparison, biological assays were made on the raw and the 'done' peas. The whole lot of one variety for animal feeding was picked and cooked on the same day. The 'done' peas were drained, cooled approximately 1½ minutes in shallow pans surrounded by ice and salt and then packed, sealed, frozen and kept in a container with dry ice.

The biological assay of the four samples of peas was based essentially upon the curative feeding test, in comparison with the response of animals receiving known amounts of the pure vitamin. The method was the same as that reported by Tressler, Mack and King ('36). Guinea pigs weighing about 300 gm. at the time of purchase were fed a Sherman basal diet (Sherman, La Mer and Campbell, '22) (rolled oats, bran, butterfat, heated skim milk powder, and salt), supplemented

¹ Mack, Tressler and Dearborn ('36) have shown that 8% trichloroacetic acid prevents enzymic oxidation of ascorbic acid in fresh peas so that regeneration with H₂S is not necessary.

with cod liver oil and 4% yeast. A liberal allowance of crisp carrots or spinach was given during a preliminary period of 10 days, to eliminate any animals that appeared subnormal in growth rate or health. They were then kept on the basal diet without a vitamin C supplement for 11 days to deplete their tissue reserves, as indicated by a lessened or negative growth rate. The test peas were then given to matched groups in such quantity that, based upon preliminary and concurrent indophenol titrations, each animal received 0.5 or 1.0 mg. of vitamin per day during a period of 14 days. For comparison,

TABLE 1
Vitamin C assay of cooked and raw peas

TEST FOOD	WEIGHT OF PEAS FED	VITAMIN LEVEL	NUMBER OF ANIMALS	AVERAGE WEIGHT AT BEGIN- NING OF TEST	AVERAGE CHANGE IN WEIGHT DURING TEST	SCURVY SCORE
	<i>gm.</i>	<i>mg. per day¹</i>		<i>gm.</i>	<i>gm.</i>	
Thomas Laxton peas, raw	2.17	0.5	6	323	+ 34	3
Thomas Laxton peas, cooked	9.10	1.0	3	316	+ 55	0
Alderman peas, raw	2.08	0.5	5	323	+ 57	2
Alderman peas, cooked	3.33	0.5	5	322	+ 40	3
Standard solution ²		1.0	6	310	+ 67	0
Standard solution		0.5	7	311	+ 41	2
Basal diet only		0.0	6	329	-113	19

¹ Quantity fed based upon values obtained from preliminary and concurrent indophenol titrations.

² The standard solution contained 1.0 and 0.5 mg. of ascorbic acid.

other groups received 0.5 and 1.0 mg. of pure vitamin per day, fed in a standard solution from graduated pipettes. Negative controls continued to receive the basal diet only.

The results of the assay, given in table 1, show close agreement in growth response and scurvy scores for the animals receiving test peas, in comparison with those receiving standard vitamin solution. A few animals in each group failed to eat their test food promptly during the first 3 days of the assay period and were therefore discarded.

TABLE 2
Vitamin C losses from peas and gain in the cooking water

LENGTH OF COOKING PERIOD IN MINUTES ¹	THOMAS LAXTON VARIETY			ALDERMAN VARIETY		
	Ascorbic acid			Ascorbic acid		
	Milligram per gram drained peas		Milligram per cubic centi- meter cooking water	Milligram per gram drained peas		Milligram per cubic centi- meter cooking water
	Wet weight	Dry weight		Wet weight	Dry weight	
0 (raw)	0.23	0.99	0.00	0.24	0.95	0.00
1	0.16	0.74	0.04	0.21	0.83	0.02
3	0.11	0.50	0.05	0.19	0.74	0.03
4	0.11	0.50	0.06	0.18	0.74	0.05
6	0.11	0.48	0.07	0.17	0.69	0.06
8	0.10	0.44	0.08	0.15	0.59	0.07
10	0.10	0.43	0.08	0.15	0.60	0.08
12	0.10	0.41	0.09	0.14	0.62	0.08
14	0.09	0.40	0.11	0.13	0.53	0.10
16 ²	0.08	0.38	0.11	0.12	0.52	0.12
18	...	...	0.13	...	...	0.14

¹ In all cases approximately 2 minutes were required to bring the water back to boiling after the peas were put into it, hence the peas cooked 1 minute had not been boiled, while those cooked 3 minutes had been boiled for 1 minute.

² Thomas Laxton peas were done in 16 minutes, the Alderman in 15 minutes.

TABLE 3
Vitamin C losses from cooked peas and gain in the cooking water. Samples not taken until peas were done

LENGTH OF COOKING PERIOD IN MINUTES ¹	CONDITION OF PEAS	THOMAS LAXTON VARIETY				ALDERMAN VARIETY			
		Ascorbic acid			Weight of cook- ing water	Ascorbic acid			Weight of cook- ing water
		Milligram per gram drained peas		Milligram per cubic centimeter cooking water		Milligram per gram drained peas		Milligram per cubic centimeter cooking water	
		Wet weight	Dry weight			Wet weight	Dry weight		
0	Raw	0.23	1.01	0	gm. 700	0.25	0.96	0	gm. 700
15	Just done	...	...	...	...	0.15	0.57	0.12	440
16	Just done	0.11	0.44	0.13	430	...	...	...	
17	Overdone	...	...	...		0.14	0.54	0.14	
18	Overdone	0.11	0.52	0.14		...	...	...	
19	Overdone	...	...	...		0.13	0.51	0.16	
20	Overdone	0.12	0.53	0.18		...	...	...	
22	Overdone	0.12	0.54	...		0.14	0.52	0.19	
24	Overdone	...	...	0.26		...	...	...	
25	Overdone	...	...	...		0.13	0.54	0.20	
28	Overdone	...	...	0.39		...	...	...	

¹ In all cases approximately 2 minutes were required to bring the water back to boiling after the peas were put into it.

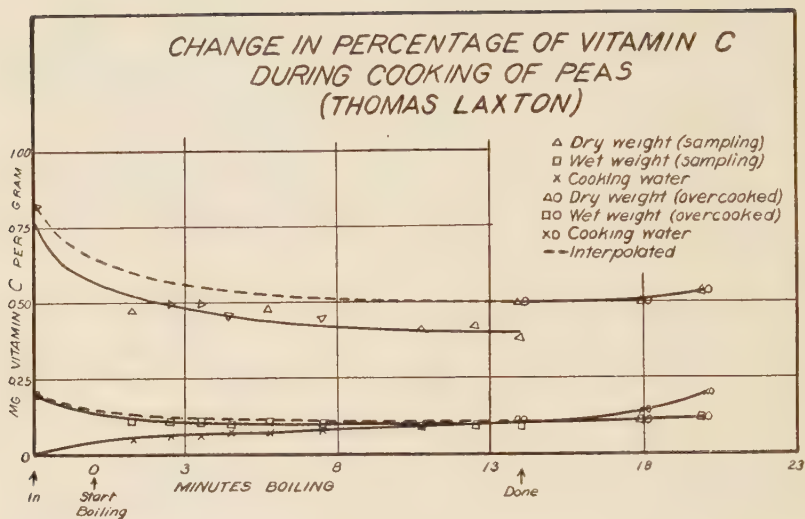


Figure 1

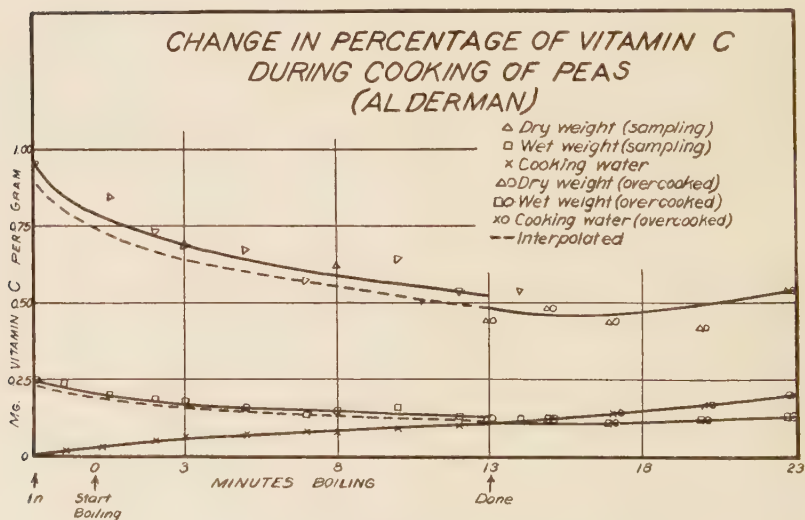
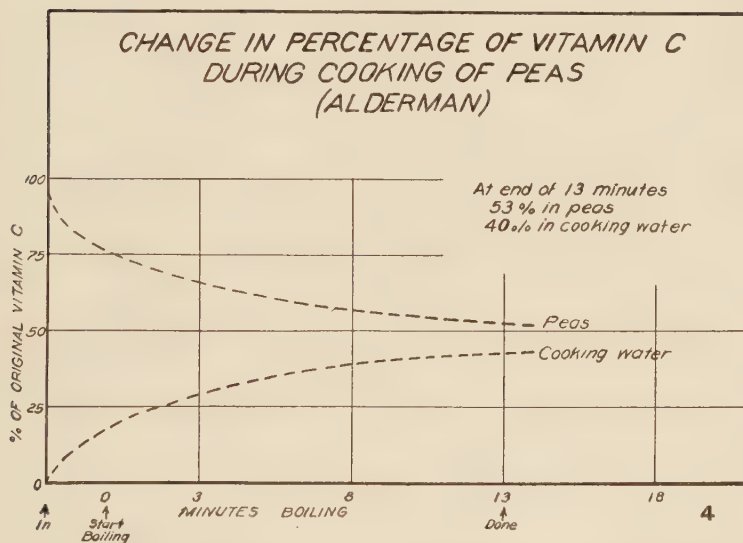
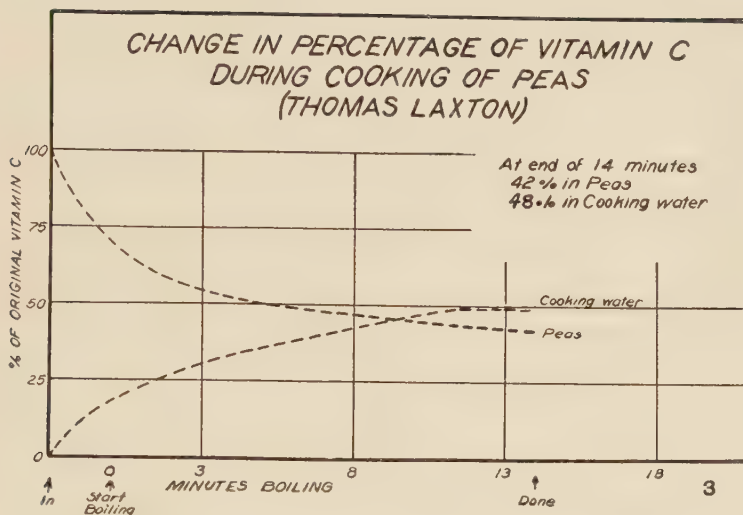


Figure 2



Figs. 3 and 4 These curves were drawn from values obtained by allowing for the vitamin C contained in the samples used for analysis. The amount of cooking water was estimated.

There was no significant loss in the titration value of the peas during the specified period of storage for the assay. During this period they were held in insulated fiber shipping cases with liberal quantities of dry ice.

2. *Losses of vitamin C during the standing of cooked peas.* The peas used in this part of the experiment were of the Telephone variety and were purchased on the open market the latter part of July. They were cooked in the same manner as the other varieties, but it was found necessary to boil them 19 minutes. To find the loss of vitamin C during standing, the cooked peas, in one serving amounts ($\frac{1}{2}$ cup), were placed on dishes. The vegetables were left thus exposed to the air at room temperature and no doubt cooled very quickly. Representative samples were removed at 5-, 15- and 70-minute intervals. The 5- and 15-minute periods represent the interval between the time the vegetable is removed from the stove and the time it may be eaten. The 70-minute period represents the time the cooked vegetable may be held for animal feeding.

DISCUSSION

The results of titrations calculated on the wet and dry basis of the peas and the results of titrations of the cooking water are presented in tables 2 and 3. The data in tables 2 and 3 are represented graphically by figures 1 and 2. The curves so constructed show the vitamin C content of the raw and cooked peas, the solution into the cooking water, and the destruction of vitamin C from the peas during the cooking and overcooking. They also show the total loss of vitamin C from the vegetable and the total loss to the cooking water at the 'done' and the 'overdone' stages, the peas being cooked with no interference from sampling. Figures 3 and 4 show the percentage of vitamin C retained in the cooking water and in the peas at the 'done' stage.

The vitamin C content of the raw peas, 0.23 and 0.24 mg. per gram for the Thomas Laxton and the Alderman, respectively, was about the same as the 0.25 mg. per gram (recalculated from biological tests) reported by Eddy, Kohman and Carlsson ('26), but was higher than that reported by Bessey

and King ('33) 0.16 mg. per gram (by dye titration). In both of these cases, the product was of uncertain variety and was purchased as a typical market vegetable. The higher content is partly explained by the fact that the peas were picked at the succulent stage and that a minimum length of time elapsed before they were tested. There is also the possibility that the one group of workers may have used varieties of peas lower in vitamin C. In a test of the vitamin C content of eighteen varieties of peas, Mack, Tressler and King ('36) found the Thomas Laxton midway in the group and the Alderman in the lower third. During cooking, the Alderman variety retained vitamin C in the peas to a slightly greater extent than did the Thomas Laxton.

In every case the greatest loss of vitamin C from the vegetable was during the first 2 minutes of cooking (the time it took the water to return to the boiling point). A possible explanation of the large initial loss is that the enzyme which catalyzes the oxidation of vitamin C was inactivated during this short period. Another factor may be that as soon as the oxygen was driven out, there was an atmosphere of steam above the water, and subsequent oxidation was decreased.

The rate of loss of vitamin C after the water came back to the boil was very low and decreased almost to zero.

The large amount of vitamin C dissolved in the cooking water is worthy of notice. This amount increased almost linearly with time. Vinokurov and co-workers ('35) and Halliday and Noble ('36) also found large amounts of vitamin C lost from vegetables to the cooking water. The vitamin C content of the cooking water from peas (0.10 to 0.12 mg. per cubic centimeter) compares favorably with that reported in the literature for tomato juice (0.14 to 0.27 mg. per cubic centimeter).

The total destruction of vitamin C in the Thomas Laxton at the 'done' stage was 10%, 42% being retained in the peas and 48% in the cooking water. The total destruction in the Alderman was 7%, 53% being retained in the peas and 40% in the cooking water.

The slight actual destruction of vitamin C may be partially explained by the low pH of the peas, which remained less than 7 throughout the cooking period. Barron, De Meio and Klemperer ('36) report "ascorbic acid is not autoxidizable in acid and neutral solutions up to pH 7.0."

Upon being overcooked, the peas apparently increased slightly in vitamin C, both on the wet and dry percentage basis. At this point, the peas and the cooking water were both reduced to a small amount, so that the rate of evaporation from the cooking water was very rapid. Another possible factor may have been introduced by the formation of small quantities of non-vitamin dye-reducing substances.

During the standing of the cooked peas, the destruction was very slight, but was greatest during the first 5 minutes, amounting to about 9% on the wet weight basis; at the end of 70 minutes, the destruction had increased to 14% of the vitamin C content of the 'done' peas. It is probable that this small destruction was caused by atmospheric oxygen and occurred largely in the peas on the surface. Consequently, after the preliminary destruction, very little further decomposition took place.

SUMMARY

1. The work shows clearly the value of the cooking water of peas from a nutritive standpoint, since about one-half of the vitamin C passes into it.
2. The greatest rate of loss of vitamin C from the peas occurred during the first 2 minutes of cooking.
3. The question of a few minutes of overcooking or undercooking of peas is not an important factor.
4. The loss of vitamin C during standing of the drained cooked vegetable at room temperature is relatively small and seems to occur during the first few minutes.

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LOSSES OF VITAMIN C DURING THE COOKING OF SWISS CHARD

Swiss chard was chosen for study because it is an easily grown hardy vegetable with a long growing season, also because it is rich in minerals and, presumably, also in vitamin C as are spinach and other greens. The only study on the vitamin C of chard found in the literature was that carried out by Wasson ('31). This experiment was on raw chard only.

Wasson ('31) reports that 2 gm. daily of the green leafy portion (with the white rib removed) of fresh raw Swiss chard was not sufficient to prevent scurvy in guinea pigs; that even 4 gm. prevented scurvy in only one case out of six although all the animals gained in weight. She also found that 4 gm. of the white rib was not protective. Recalculated on the basis that 0.5 mg. ascorbic acid per day is required to protect a guinea pig from scurvy (Bessey and King, '33), this means that the green leafy chard contained less than 0.125 mg. of ascorbic acid per gram and the white rib considerably less than this amount. Wasson ('31) concludes that "the vitamin C potency of Swiss chard is very low." She did not name the variety of chard used or the kind of soil on which it was grown. The chard was freshly cut, but Wasson reports that the animals on the green leafy portion were slow about eating it and some of them would have part of the chard left in their cages after 5 or 6 hours. This would probably decrease the amount of vitamin C present in the chard by the time it was consumed.

The purpose of this experiment was to determine not only the vitamin C content of the raw chard, but also that of the cooked chard and the cooking water at the 'done' stage and at various intermediate stages. The amounts of ascorbic acid

reported are those obtained after reduction with hydrogen sulphide inasmuch as this represents the biologically active vitamin C present. The aim in cooking was to make the cooked vegetable look attractive and taste well, with the loss of nutrients a secondary consideration.

EXPERIMENTAL

Two varieties of Swiss chard, Lucullus and Fordhook, were grown on upland Ontario clay loam soil at Geneva, New York, and were cut during July. The Lucullus is dark green and is the market preference at present due to the fact that it does not wilt as readily as the lighter colored chard. Both varieties have large white midribs. Vitamin C determinations were made of the leaf with the midrib left intact, with the midrib removed, and of the stems alone. Analysis was also made of leaves which were chopped and those which were cut with scissors. The chard was gathered, washed, the clinging moisture removed by means of electric fans, the stems removed, the uncut leaves cooked and analyzed in as short a time as possible.

In cooking, a 3-quart enamel pan with an inside diameter of 7 inches was used. The pan and gas burner were placed on a balance so that the weight of the pan and its contents was obtainable at any stage. A manometer was connected between the gas supply and stove so that it was possible to regulate the amount of evaporation of the cooking water making it practically the same in successive cookings. Three hundred and fifty grams of chard (four servings) were used with 1200 cc. of water and $1\frac{1}{2}$ teaspoons of salt. The chard was dropped into the rapidly boiling water and the time counted from the beginning of cooking, as the water did not stop boiling. The tap water was boiled several minutes before the chard was added. An arbitrary stage of 'doneness' was determined in advance by several judges, testing with a fork and 'biting.' The boiling time for both varieties was 10 minutes. Due to the fact that it was impossible to secure samples of whole leaves (vitamin C was found to be unevenly distributed in the green leafy part and the white portion of the midrib) during

the cooking and also to standardize the draining of the samples it was found necessary to have separate cookings for each of the intervals analyzed, namely, 2, 4, 6, 8, 10 ('done'), and 14 ('overdone') minutes. At the end of each of these cooking periods the chard was drained for 1 minute, samples of whole leaves removed and the remainder weighed immediately. Samples of the cooking water were also removed and the remainder weighed immediately. The weights of the total chard and the total cooking water were thus easily obtained.

After trying 8% acetic, 8% trichloroacetic, 4% lactic, 1 N and 2 N sulphuric acids, all containing 2% metaphosphoric acid, it was decided to use 8% acetic acid for extracting as it gave as clear a solution as any of the acids and also resulted in a color which gave as little trouble as any acid in duplicating the titration end point.

The method of sampling was the same as that reported by Fenton, Tressler and King ('36). The method of extraction, of standardization of the dye, and titration were essentially those of Bessey and King ('33) but modified by using for the extraction an acid solution containing 2% metaphosphoric acid according to Mack and Tressler ('37). The 2,6 dichlorophenolindophenol dye was standardized with pure ascorbic acid. A total of 100 cc. of acid was used, 30 cc. being used in grinding the chard with sand in a mortar; the remainder was used in three rinsings. The first mixture was centrifuged and the liquid decanted into a 100-cc. volumetric flask. The rinsings were added, the mixture centrifuged and the liquid decanted between each addition of acid. Aliquots were titrated with the dichlorophenolindophenol dye immediately.

Since it was found that during extraction with the acetic metaphosphoric acid mixture there was considerable oxidation of the titratable ascorbic acid to the dehydro form, aliquots were taken and the reversibly oxidized ascorbic acid was reduced immediately according to the general method of Tillmans, Hirsch and Jackisch ('32) with the following modification: hydrogen sulphide was bubbled slowly through the sample for 10 minutes, the container stoppered and allowed to stand 20 minutes. The excess of hydrogen sulphide was

removed with a rapid stream of carbon dioxide. The samples were then titrated with the dye, providing a measure of the total vitamin C content.

For purposes of comparison, biological assays were made on the raw and 'done' chard. The whole lot of one variety (Lucullus) for animal feeding was gathered the same day. Part of it was frozen directly with no blanching while part of it was cooked and drained, cooled in shallow pans surrounded by ice and salt and then packed, sealed, frozen, and kept in a container with dry ice.

The curative type biological assay was used, as in the earlier investigations of this series (Tressler, Mack and King, '36). Guinea pigs weighing approximately 225 to 250 gm. were placed in individual cages where they received the modified Sherman et al. basal diet ('22) (oats, bran, milk powder, irradiated yeast, salt and butterfat) and spinach until they had reached an average weight of approximately 260 gm. Animals that were subnormal in growth rate or significantly abnormal in any respect were discarded. They were then depleted of their tissue reserves of vitamin C by being kept on the basal diet only for 13 days. Weighed quantities of the test foods were fed daily during the ensuing 21 days, the quantity fed being based upon the dichlorophenolindophenol titration value after reduction with hydrogen sulphide. A feeding level of 0.5 mg. per day permits only partial recovery from mild scurvy during the 21-day period, hence this level is suitable for optimum sensitivity.

A summary of the data is given in table 1. It is evident that the biological response of the three groups was comparable in both weight change and scurvy score. The record for the raw chard group was not quite as good as for the other two groups, however. This was probably due in part to the rapid rate of decomposition of the dehydro-ascorbic acid into its irreversible product.

The titration values of the raw and the cooked chard used in the biological assays, after storage in dry ice, at the beginning of and during the test period did not show significant variation beyond that inherent in sampling such products.

The raw chard contained 0.35 mg. of ascorbic acid per gram, while the cooked chard contained only 0.16 mg. of ascorbic acid per gram. The reduction and titration of the vegetable extracts were always checked with a standard vitamin solution to avoid an error due to residual hydrogen sulphide or to re-oxidation of the vitamin. The rate of loss in dehydro-ascorbic acid was about 50% every 3 hours when the frozen raw unblanched chard was allowed to stand exposed at room temperature.

TABLE 1
Biological assay of the antiscorbutic value of raw and cooked chard after storage in dry ice

TEST FOOD	WEIGHT ¹ OF CHARD FED	VITA- MIN LEVEL	NUM- BER OF ANI- MALS	AVERAGE WEIGHT AT BE- GINNING OF DE- PLETION	AVERAGE WEIGHT AT BE- GINNING OF FEED- ING PERIOD	AVERAGE WEIGHT AFTER 21 DAYS	AVERAGE GAIN	AVERAGE SCURVY SCORE
	<i>gm.</i>	<i>mg. per day</i>		<i>gm.</i>	<i>gm.</i>	<i>gm.</i>	<i>gm.</i>	
Vitamin solution		0.5	8	263	272	284	+ 12	3
Raw chard	1.42	0.5	6	251	291	290	— 1	4
Cooked chard	3.12	0.5	8	253	276	294	+ 18	2
Vitamin solution		1.0	4	268	284	348	+ 64	1
Negative control		0.0	4	260	298	176 ²	—122	16

¹Quantity fed based upon values obtained from preliminary and concurrent dichlorophenolindophenol titrations.

²Average weight at end of survival period.

DISCUSSION

The results of titration calculated on the wet and dry basis of the chard per gram and the results of titration of the cooking water per cubic centimeter are presented in table 2. The data in table 2 are presented graphically by figures 1 and 2. The curves so constructed show the milligrams of vitamin C per gram of the raw and cooked chard (on both wet and dry bases) and per cubic centimeter of the cooking water. The data in table 3 show the vitamin C in the total chard and in the total cooking water at various cooking intervals, also the percentage loss of vitamin C from the chard and the percentage gain to the cooking water.

TABLE 2
Vitamin C losses from Swiss chard (per gram) and gain in the cooking water
(per cubic centimeter)¹

LENGTH OF COOKING PERIOD IN MINUTES ²	LUCULLUS VARIETY			FORDHOOK VARIETY		
	Ascorbic acid			Ascorbic acid		
	Milligram per gram drained chard		Milligram per cubic centimeter cooking water	Milligram per gram drained chard		Milligram per cubic centimeter cooking water
	Wet weight ³	Dry weight		Wet weight ⁴	Dry weight	
Averages						
0 (raw)	0.43	3.8	0	0.36	3.6	0
2	0.25	2.6	0.04	0.22	2.5	0.02
4	0.21	2.4	0.05	0.19	2.3	0.03
6	0.16	1.9	0.07	0.17	2.0	0.04
8	0.15	1.8	0.08	0.14	1.8	0.05
10 (done)	0.16	1.8	0.09	0.12	1.3	0.06
Averages						
0 (raw)	0.37	3.7	0	0.37	3.6	0
10 (done)	0.16	1.8	0.07	0.14	1.6	0.06
14 (overdone)	0.14	1.2	0.10	0.10	1.0	0.08

¹ There was no interference from sampling in any of the cookings. The amounts of ascorbic acid shown in this table were those found after reduction with hydrogen sulphide.

² In all cases the water did not stop boiling when the chard was added.

³ In terms of the raw vegetable these values were 0.43, 0.28, 0.24, 0.18, 0.17, 0.17, 0.37, 0.18 and 0.11, respectively.

⁴ In terms of the raw vegetable these values were 0.36, 0.24, 0.22, 0.19, 0.16, 0.14, 0.37, 0.15 and 0.10, respectively.

TABLE 3
Total vitamin C in the chard and in the cooking water¹

LENGTH OF COOKING PERIOD IN MINUTES ²	LUCULLUS VARIETY				FORDHOOK VARIETY			
	Ascorbic acid in milligram		% of original ascorbic acid in		Ascorbic acid in milligram		% of original ascorbic acid in	
	Drained chard	Cooking water	Drained chard	Cooking water	Drained chard	Cooking water	Drained chard	Cooking water
Averages								
0 (raw)	151	0	100	0	125	0	100	0
2	100	37	66	24	85	23	68	18
4	85	58	56	38	77	33	61	26
6	64	72	42	48	66	44	53	35
8	60	77	40	51	58	51	46	41
10 (done)	59	80	39	53	50	56	40	45
Averages								
0 (raw)	134	0	100	0	130	0	100	0
10 (done)	62	66	46	49	55	57	42	44
14 (overdone)	39	83	29	62	32	73	25	56

¹ There was no interference from sampling in any of the cookings. The amounts of ascorbic acid shown in this table were those found after reduction with hydrogen sulphide.

² In all cases the water did not stop boiling when the chard was added.

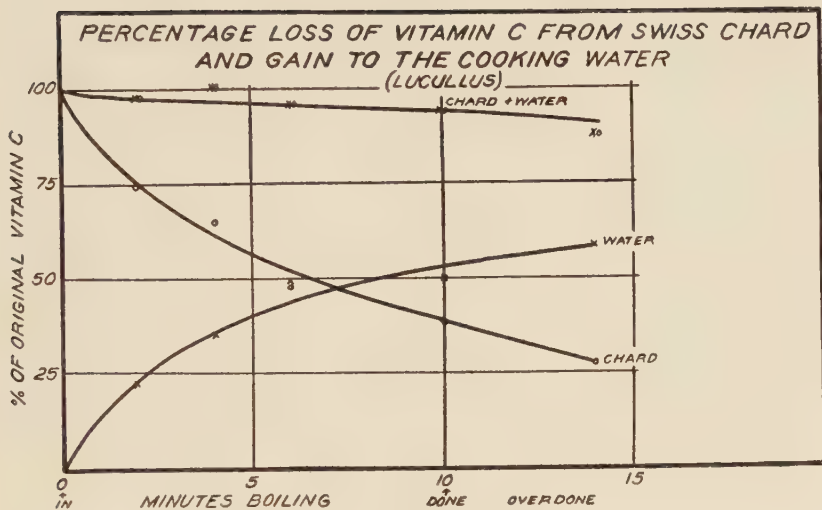


Figure 1

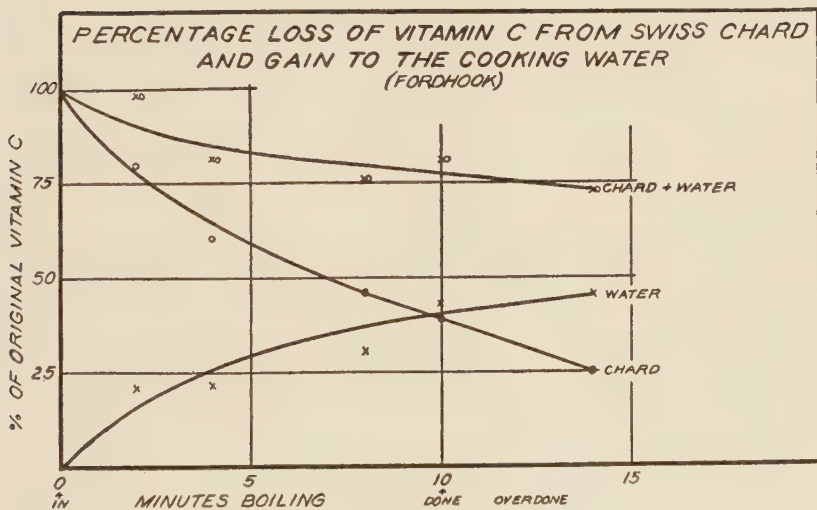


Figure 2

The vitamin C content of the green portion of the leaves with the midrib cut out was found to be about 0.40 mg. per gram, while that of the stems was 0.08 mg. per gram (wet weight). The midrib was left in the leaves (although the stems were cut off) during the experiment as the housewife does not discard the midrib. Furthermore, it was found that upon removing the midrib the cooked leaves contained only two-thirds the amount of vitamin C per gram that they did if the midrib was left intact. This loss from the cut surface is to be expected in view of the great solubility of the vitamin in water. The presence of the midrib meant considerable variation in results, as the proportion of midrib varied in size in different leaves. The size of the leaves varied somewhat also. The extent of drainage proved to be a variable factor. There was less loss of vitamin C from raw chard when it was cut with scissors than when it was chopped with a knife due perhaps to less bruising of the tissues.

The Lucullus variety of chard contained slightly more vitamin C than did the Fordhook variety. This may be partially explained by the fact that the latter contained a larger proportion of midrib.

The average vitamin C content of the raw chard, 0.40 and 0.37 mg. per gram (wet weight) and 3.74 and 3.60 mg. per gram (dry weight), for the Lucullus and the Fordhook varieties, respectively, was greater than that found by Wasson ('31) (0.125 mg. per gram wet weight in the green leafy portion, assuming that 0.5 mg. ascorbic acid per day is required to protect a guinea pig from scurvy). In both cases the chard was freshly cut. Since the destruction of the vitamin by oxidation is very rapid in chard, Wasson's low values may be partially explained by the fact that the animals on the green portion of the leaf were always slow about eating it and some of them would have part of the chard left in their cages after 5 or 6 hours.

The fact that the reduced and the reduced plus the reversibly oxidized ascorbic acid were nearly the same after the first 2 minutes of cooking indicates that probably the so-called ascorbic acid oxidizing enzyme was inactivated during this

short period. This finding agrees with that of Fenton, Tressler and King ('36) in a study of peas. Kertesz, Dearborn and Mack ('36) report that the ascorbic acid oxidase in other vegetables is inactivated by heating at 100°C. for 1 minute. The rate of loss after the first 2 minutes of cooking was decreased and most of the loss was found in the cooking water.

During a standard cooking period about half of the vitamin C was dissolved in the water. Vinokurov and co-workers ('35), Halliday and Noble ('36), Fenton, Tressler and King ('36) and Gould, Tressler and King ('36) found similarly large amounts of vitamin C lost from other vegetables to the cooking water.

The average destruction of vitamin C in the Lucullus variety at the 'done' stage was 6%, 41% being retained in the chard and 53% in the cooking water. The total destruction in the Fordhook variety at the 'done' stage was 16%, 40% being retained in the chard and 44% in the cooking water.

SUMMARY

1. The leaf portion of fresh raw Swiss chard is a good source of vitamin C (the leaf minus the stem contains about 0.38 mg. per gram).

2. The stem of fresh raw Swiss chard is a relatively poor source of vitamin C (about 0.08 mg. per gram).

3. Cooked chard contains from 0.14 to 0.18 mg. of vitamin C per gram.

4. The two varieties of Swiss chard studied contained about the same amount of vitamin C.

5. About one-half of the original vitamin C passes into the cooking water by the method of cooking used.

6. The so-called ascorbic acid oxidizing enzyme is very active in Swiss chard as indicated by the large amount of dehydro-ascorbic acid found in raw chard after extraction with acetic and metaphosphoric acid. The enzyme is inactivated during the first few minutes of cooking.

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LOSSES OF VITAMIN C DURING BOILING AND STEAMING OF CARROTS

A survey of the literature shows only one study reporting a comparison of the losses of vitamin C during the boiling and steaming of vegetables. Since it has been found by Fenton, Tressler, Camp, and King (1937) that during the cooking of fresh peas about 50 per cent of the vitamin C is lost to the cooking water by solution, it seems probable that in steaming, where the vegetables are not immersed in water, the loss would be smaller. Carrots lend themselves well to both methods of cooking and were, therefore, chosen for this study in spite of the fact that they are known to be low in vitamin C. Raw carrots of unnamed varieties have been reported to contain .012, .017,* .033,* and .041 mg. of ascorbic acid per gram by McHenry and Graham (1935); Langley, Richardson, and Andes (1933); Wasson (1931); and Fellers (1935), respectively. The change in the content of this vitamin (owing to the boiling of carrots, as reported by these workers, varied from a loss of 50 per cent to a gain of 100 per cent. In a publication by Halliday and Noble (1936) a loss of 56 per cent from the carrots and a gain to the cooking water of 22 per cent during a 30-minute cooking period is reported. They do not give the actual vitamin C content of their samples. None of the above workers made a distinction between the unoxidized and reduced ascorbic acid with the exception of McHenry and Graham, who found .012 mg. of "free" and .009 mg. of "combined" ascorbic acid per gram of raw carrots.

The purpose of this study was to compare the losses of vitamin C from a known variety of carrots of known history when cooked by the boiling and steaming methods.

EXPERIMENTAL PROCEDURE

The Chantenay variety of carrots selected for this study was grown on Arkport fine sandy loam soil at Geneva, New York. They were pulled at the mature stage (about six carrots to the pound) each morning shortly before they were used and were prepared for cooking by washing and cutting crosswise in one-eighth-inch slices. This method of cutting gives a large amount of cut surface but is a very commonly used one, and it was necessary to have cooked pieces of such size and shape that they could be quickly immersed in acid in a weighing bottle.

*Recalculated on the assumption that .5 mg. of ascorbic acid per day is required for the protection of a guinea pig from scurvy, Bessey and King (1933).

Cooking in Boiling Water: This method was essentially that of Halliday and Noble (1933). The carrots, 325 grams or four servings, were plunged into 750 c.c. of rapidly boiling tap water containing one teaspoon of salt. A three-quart enamel pan with an inside diameter of seven inches was used. The water was boiled a short time before the carrots were added. The cover was left off to allow for removal of samples during the cooking. The evaporation in successive cookings was maintained at practically the same rate by means of a manometer, as described by Fenton, Tressler, Camp, and King (1937). The heat was so controlled that the water came back to the boil within two minutes after the carrots were added. It was found necessary to cook them 15 minutes.

The method of sampling the carrots and cooking waters, at intervals during the cooking periods, was the same as that reported by Fenton, Tressler, and King (1936). Samples were also taken at the done stage from cookings in which there had been no interference from previous sampling.

Steaming: An enamel steamer with a diameter of eight and one-half inches and an upper inset pan two and three-fourths inches deep was used. The entire steamer was hot and the water boiling when the 325 grams of sliced carrots were added. Different cookings were steamed 20 (done) and 25 (overdone) minutes. Samples of the carrots for vitamin C and moisture determinations were taken at the end of the cooking period only, since the cover was left on the steamer during the entire time.

The methods of extraction and titration were essentially those of Bessey and King (1933) as modified by Mack and Tressler (1937). A mixture of five per cent sulphuric and two per cent metaphosphoric acid was used for extraction. The dichlorophenolindophenol dye used was standardized daily with pure ascorbic acid. Blanks were run with the dye.

Since the body is able to use the dehydro as well as the reduced form of ascorbic acid, determinations were made of both the reduced and the reduced plus the reversibly oxidized ascorbic acid. The procedure employed in regeneration was that of Tillmans, Hirsch, and Jackisch (1932) with the following modification as to time: hydrogen sulphide was bubbled through the extract for 10 minutes, the container was stoppered and allowed to stand for 20 minutes. The excess hydrogen sulphide was then removed with a stream of carbon dioxide and the extract titrated.

For the biological assay, samples of the sliced raw carrots were blanched in water at 100°C.(212°F.) for 120 seconds. Since it has been found that the freezing of vegetables causes no loss of vitamin C while blanching does cause loss, as noted by Fenton, Tressler, and King (1936), a larger quantity was necessary for feeding than would

have been the case if the raw carrots had been frozen without blanching. The blanched and the cooked samples, which were cooled approximately four minutes in shallow pans surrounded by ice and salt, were packed, sealed, frozen, and stored in a container with dry ice. The curative method described previously by Tressler, Mack, and King (1936) was used with the exception that the curative feeding period was extended to 21 days.

The results of the assay (Table 1) show very close agreement in growth response and scurvy scores of the animals receiving the cooked carrots in comparison with those receiving standard vitamin solution. There was fair agreement in response of the animals receiving the blanched carrots.

TABLE 1
*Vitamin C Assay of Blanched and Cooked Carrots
After Storage With Dry Ice*

Test food	Weight of carrots fed	Vitamin equivalent per day	Number of animals	Average weight at beginning of test	Average change in weight during test	Average scurvy score (0-24)
	<i>gm.</i>	<i>mg.</i>		<i>gm.</i>	<i>gm.</i>	
Cooked carrots.....	10	0.50	10	341	+74	3.6
Blanched carrots.....	12	0.55	10	338	+95	2.3
Vitamin solution.....	....	0.50	10	337	+75	3.6
Positive controls.....	....	1.00	3	332	+85	0.0
Negative controls.....	....	0.00	4	300	—98	18.0

DISCUSSION

The results of the vitamin C determinations are presented (Tables 2 and 3). The raw carrots contained an average of .044 mg. of ascorbic acid and .069 mg. of reduced plus reversibly oxidized ascorbic acid per gram. The former varied from .032 to .052 and the latter from .044 to .069 mg. per gram. Some of the ascorbic acid was apparently oxidized to the dehydro form during the very thin slicing of the raw carrots which was necessary to facilitate grinding. The vitamin C content both before and after reduction was greater than that reported by other workers, .012 to .033 mg. per gram, determined by either the biological or chemical methods of determination. The higher value may be due to variety, growing conditions, maturity, or freshness.

At the end of the cooking period the boiled carrots retained .036 mg. of ascorbic acid per gram. There was some increase in titration value after regeneration of the carrot extract. It seems probable that this increase was due, however, to the formation of non-vitamin dye-reducing substances. Hence the values for the cooked carrots given in the tables are those obtained before regeneration. At the end of the boiling period the cooking water contained .017 mg. of

vitamin C per gram. There was practically no increase in titration value after treatment of the cooking water with hydrogen sulphide. This is in agreement with the data on the cooking water of carrots reported by Mack and Tressler (1937) with the use of the same extractants.

The total destruction of vitamin C was only 11 per cent, 56 per cent being retained in the carrots and 33 per cent in the cooking water. In determining the unoxidized acid Halliday and Noble (1936) found a total destruction of 34 per cent, 44 per cent being retained in the carrots and 22 per cent in the cooking water. The carrots they used were purchased in the open market, were of un-

TABLE 2
Vitamin C Loss From Carrots and Gain to Cooking Water

Length of cooking period ¹	Ascorbic acid						
	Drained carrots		Cooking water ⁴	In total drained carrots	In total cooking water	Per cent of original in	
	Wet weight	Dry weight				Carrots	Cooking water
<i>min.</i>	<i>mg. per gm.</i>	<i>mg. per gm.</i>	<i>mg. per c.c.</i>	<i>mg.</i>	<i>mg.</i>		
0 (raw)	.069 ²	.59	.000	22.4	0.0	100	0
2	.056	.47	.005	.....	.....	.....	....
4	.....	.....	.006	.....	.....	.....	....
6	.050	.45	.009	.....	.....	.....	....
8	.047	.45	.010	.....	.....	.....	....
10	.047	.44	.012	.....	.....	.....	....
12	.043	.41	.016	.....	.....	.....	....
15	.040	.38	.021	.....	.....	.....	....
Samples not taken until carrots were done.							
0 (raw)	.064	.46	.000	20.8	0.0	100	0
15	.036 ³	.32	.017	11.6	6.8	56	33

¹In all cases approximately two minutes were required to bring the water back to boiling after the carrots were put into it, hence the carrots cooked 15 minutes had been boiled 13 minutes. ²Obtained previous to reduction, .050. ³When computed in terms of raw vegetable, .038. ⁴Change in vitamin content of water owing to evaporation and removal of samples as well as solution from the vegetable.

known variety, and while they were cooked by essentially the same method, they were cooked a longer period of time (30 minutes instead of the 15 minutes found necessary to tenderize the freshly pulled Chantenay sliced carrots). The increase upon cooking from .012 to .026 mg. per gram of free ascorbic acid found by McHenry and Graham (1935) may be because (1) there was probably a considerable amount of the reversibly oxidized ascorbic acid formed during the grinding of the raw vegetable and this was not determined; (2) the so-called ascorbic acid oxidizing enzyme was inactivated during the first few minutes of cooking; and (3) non-vitamin dye-reducing substances were formed during cooking.

At the end of the 20-minute cooking period the steamed carrots lost only 14 per cent and the "overdone" only 15 per cent of their vitamin C. This small decrease might be expected because (1) most of the loss during the boiling of the carrots was found to be by transfer into the cooking water and (2) the carrots were sliced thin so that the heat which inactivates the so-called oxidizing enzyme could penetrate quickly.

TABLE 3
Vitamin C Loss From Carrots by Steaming

Length of steaming period	Ascorbic acid			
	Drained carrots		In total carrots	Per cent of original in drained carrots
	Wet weight	Dry weight		
<i>min.</i>	<i>mg. per gm.</i>	<i>mg. per gm.</i>	<i>mg.</i>	
0 (raw)	.055 ¹	.41	17.9	100
20 (done)	.050 ²	.37	15.3	86
0 (raw)	.051 ³	.41	16.6	100
25 (over done)	.047	.37	14.1	85

¹ Obtained previous to reduction, .043. ² When computed in terms of raw vegetable, .038. ³ Obtained previous to reduction, .044.

SUMMARY

1. Fresh raw carrots of the Chantenay variety contain from .044 to .069 mg. of vitamin C per gram.
2. Boiled sliced carrots contain about .036 mg. of vitamin C per gram or 56 per cent of their original vitamin C.
3. During a 15-minute cooking period almost two-fifths of the vitamin C present in carrots is dissolved in the water, but only about 11 per cent is destroyed.
4. Steaming carrots permits an 86 per cent retention of vitamin C.

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LOSSES OF VITAMIN C DURING COMMERCIAL FREEZING, DEFROSTING, AND COOKING OF FROSTED PEAS

The vitamin C content of frosted* peas is of interest inasmuch as 16,000,000 pounds or one-half the frozen vegetable pack of 1936, were peas, according to Tressler (1937). Investigators report the vitamin C content of fresh raw peas from .14 to .46 mg. per gram, but there is little information available as to the vitamin C content of frosted vegetables. It is known that freezing alone does not affect the vitamin C content of peas, as noted by Fenton, Tressler, and King (1936), but frosted peas as they appear on the market have been subjected to a number of processes in addition to actual freezing. Such processes include blanching, cooling, packaging, sealing, and shipping and it may well be expected that one or several of these steps will result in loss of some of the vitamin C content.

One study on the vitamin C content of frosted peas found in the literature was made by Fellers and Stepat (1936) who found a decrease from .35 to .13 mg. of vitamin C per gram during the processes involved in preparing and marketing frosted peas. This marked difference may be due to sampling as well as to losses in blanching, cooling, etc. The vitamin C content of the fresh peas was based on 45 samples and of the frosted peas on only 13 samples which apparently were not paired with the fresh. During the defrosting of peas (two to six hours) they found a further loss to .041 mg. per gram. This large loss may be because (1) the so-called ascorbic acid-oxidizing enzyme was not completely inactivated during the short blanching period which was used and (2) no tests were made for any dehydroascorbic acid which might have been formed during the standing of the peas.

A report on the cooking losses of vitamin C from frosted peas was also made by these workers. They used a small amount of peas (140 grams) with a very small amount of water (60 grams) and their method involved evaporation of "practically all of the added water." It should be noted that whatever small amounts of cooking water were left were not analyzed for vitamin C. Analyses in this laboratory of small amounts of cooking water unabsorbed by peas have indicated that it contains a high concentration of the vitamin. Thus, while the vitamin content of the peas themselves decreased, some of the vitamin in the above study would probably have been found in any small portion of cooking water if it had been analyzed.

*"Frosted" is a term applied to quick-frozen foods. The peas used in this study were furnished by the Birdseye Laboratories.

Moreover, the large proportion of peas to cooking water used in the study by Fellers and Stepat would involve a relatively long time to bring the water back to boiling after the addition of peas. Increasing the period of time of holding peas at this range of temperature would probably increase actual destruction of the vitamin. Furthermore, the peas used by these workers had been blanched, prior to freezing, by subjecting them for 40 seconds to steam at 100°C.(212°F.). It is doubtful whether this treatment would completely inactivate the enzymes. Consequently, owing to enzymic action, the vitamin C in these vegetables was subject to oxidation during the time it took the water to come back to the boiling point after the peas were added. Thus there were probably two factors contributing to the loss observed by these workers: (1) transfer of vitamin C from vegetable to cooking water and (2) actual destruction of vitamin C by enzymic oxidation permitted by the particular methods of blanching and cooking.

Recently, Jenkins, Tressler, and Fitzgerald (1937), in a study of the changes in ascorbic acid content of peas during commercial preparation and freezing, found a loss of 30 per cent of the total amount present, of which ten per cent occurred during blanching. The most rapid loss of ascorbic acid was found to occur during the cooling and washing operations subsequent to blanching. These workers also report that thawing peas results in no appreciable loss of vitamin C.

In view of the small amount of work which has been done on frosted peas it seemed worth while to investigate the following factors affecting the loss of vitamin C in these products: (1) current method of putting frosted peas on the market, (2) customary household holding of frosted peas, (3) cooking of frosted peas. Such a study will indicate the relative value of cooked fresh peas and cooked frosted peas as sources of vitamin C.

EXPERIMENTAL PROCEDURE

The Thomas Laxton variety of peas was used. The peas were shelled, washed, blanched 60 seconds in boiling water or 120 seconds in steam at 100°C.(212°F.), cooled, and frozen two hours at -17.8°C.(0°F.) in regular 10- or 12-ounce, wrapped, waxed cartons in a Birdseye Multiplate Freezer. They were packed in dry ice and shipped from Albion to Geneva, New York, and held at -40°C.(-40°F.). At this temperature no loss in vitamin C content occurs, according to Fenton, Tressler, and King (1936).

Vitamin C determinations were made on the (1) raw fresh peas; (2) raw frosted peas (a) taken directly from storage at -40°F., (b) held in a refrigerator at 4.4°C.(40°F.) for 16 hours, (c) held at room temperature for one and five hours; (3) both raw and cooked frosted peas that had been (a) taken directly from storage at -40°F.,

(b) held in a refrigerator at 40°F. for 16 hours; that is, cooked fresh peas were compared with cooked frosted peas as sources of vitamin C. A comparison was also made of the vitamin C content of peas from the same lot cooked (1) with the flame so regulated that the water came to a boil (a) in two and (b) in four minutes, (2) with the cooking utensil (a) uncovered, (b) covered.

The method of cooking the frosted peas was that given on the package. A three-quart enamel pan with an inside diameter of seven inches was used. The 283.5 grams of peas were added to 292 c.c. of rapidly boiling tap water containing one-half teaspoon of salt. An arbitrary stage of "doneness" was determined in advance by testing with a fork and "biting." It took eight minutes to reach this stage in all cases.

The rate of evaporation in successive cookings was controlled by means of a manometer as described by Fenton, Tressler, Camp, and King (1937). The heat was so controlled that the water in which the peas taken from storage at -40°F. and the water in which the peas taken from the refrigerator were cooked came back to the boil in four and two and one-half minutes, respectively. Peas from the same lot were cooked with the cooking utensil covered and uncovered.

The method of sampling the peas and cooking water at intervals during the cooking periods was the same as that used by Fenton, Tressler, and King (1936) on fresh peas. There was no interference from sampling in further cookings which were made to the done stages.

The methods of extraction, of standardization of the dye, and titration were essentially those of Bessey and King (1933) as modified by Mack and Tressler (1937). Since the peas had been frozen, and as a result were very easily crushed even in the raw state, the analysis of duplicate samples for ascorbic acid required less than one hour. A mixture of eight per cent of trichloroacetic and two per cent of metaphosphoric acid was used for extraction. Aliquots of the vegetable extracts and the cooking water were titrated with the 2, 6 dichlorophenolindophenol dye. The dye was standardized daily with pure ascorbic acid. Blanks were run with the dye. Since the body is able to use the dehydro as well as the reduced form of ascorbic acid, aliquots of the vegetable extracts and the cooking waters were immediately regenerated with hydrogen sulphide, according to the method of Tillmans, Hirsch, and Jackisch (1932) as modified by Mack and Tressler (1937). In view of the close agreement obtained between the chemical titrations and the biological assays of the two varieties of frozen unblanched peas and frozen cooked peas, as shown by Mack, Tressler, and King (1936) and Fenton, Tressler, and King (1936), it was not deemed necessary to check the chemical findings with a biological assay in this study.

DISCUSSION

The effects of commercial freezing and of defrosting frosted peas on the vitamin C content are given (Table 1). The results of cooking the frosted peas (1) taken directly from -40°F. and (2) held in the refrigerator are shown (Tables 2 and 3).

No increase in the titration value was obtained after treatment of the vegetable extracts with hydrogen sulphide, probably because the blanching periods were sufficient to inactivate the so-called ascorbic acid oxidizing enzyme.

The vitamin C content of the raw peas, about .25 mg. per gram, was the same as that obtained by biological assay of an unnamed variety of peas by Eddy, Kohman, and Carlsson (1926) and is also

TABLE 1
*Vitamin C Content of Fresh Peas, Frosted Peas,
and Frosted Peas Upon Standing*

Treatment	Temperature	Ascorbic acid	
		Wet weight	Dry weight
		<i>mg. per gm.</i>	<i>mg. per gm.</i>
Raw, unfrozen	Fresh	.25	1.05
Uncooked, frosted	Weighed in $-17.8^{\circ}\text{C.}(0^{\circ}\text{F.})$ room.	.18	0.65
Uncooked, frosted	Taken directly from 0°F. room but weighed in room at $26.7^{\circ}\text{C.}(80^{\circ}\text{F.})$.	.18	0.65
Uncooked, frosted	Held in an electric refrigerator at $4.4^{\circ}\text{C.}(40^{\circ}\text{F.})$ for 16 hours.	.18	0.65
Uncooked, frosted	Held at room temperature 80°F. for 1 hour.	.18	0.65
Uncooked, frosted	Held at room temperature 80°F. for 5 hours.	.18	0.65

about the same as that reported for the Thomas Laxton variety (.23 mg. per gram) by Fenton, Tressler, and King (1936). It is higher than the .16 mg. per gram reported by McHenry and Graham (1935) for an unnamed variety of peas.

The frozen peas contained .18 mg. of vitamin C per gram wet weight, or a loss of about 38 per cent. This loss must be due to blanching, chilling, and packaging since no loss occurs during the actual freezing and holding of peas at such low temperatures, according to Fenton, Tressler, and King. Blanching is probably more largely responsible for the loss than are the other processes, since in the cooking of fresh peas the greatest loss of vitamin C occurs during the first two minutes, according to Fenton, Tressler, and King.

When frosted peas were taken directly from storage at -40°C. (-40°F.) and then held in cartons (1) at room temperature (80°F.) with the seal broken for one and five hours, (2) in a household

electric refrigerator at 40°F. for 16 hours with the seal unbroken, there was no appreciable loss of vitamin C. Holding frosted peas, except at below freezing temperatures, however, is not advisable because of spoilage which may occur. The rapid loss of vitamin C during the defrosting of frosted peas, observed by Fellers and Stepat (1936), may be because the so-called ascorbic acid-oxidizing enzyme was not inactivated during the blanching of the raw peas.

During cooking there was very little destruction of vitamin C but only a loss to the cooking water. This was true whether the peas were taken directly from storage at —40°F. or from the refrigerator.

TABLE 2
Vitamin C Losses From Frosted Peas Taken Directly From Storage at —17.8°C.(0°F.), and Gain to Cooking Water

Cooking period ¹	Ascorbic acid						
	Drained peas ²		In cooking water ⁴	Total in		Original in	
	Wet weight	Dry weight		Drained peas	Cooking water	Drained peas	Cooking water
min.	mg. per gm.	mg. per gm.	mg. per c.c.	mg.	mg.	pct.	pct.
0 (uncooked)	.18	.65	.00	.....	.....	.....	.....
3	.15	.60	.02	.....	.....	.....	.....
4	.14	.59	.02	.....	.....	.....	.....
5	.13	.56	.04	.....	.....	.....	.....
6	.13	.56	.05	.....	.....	.....	.....
7	.12	.54	.06	.....	.....	.....	.....
8 (done)	.11	.52	.08	.....	.....	.....	.....
No sampling until peas were done.							
0 (raw)	.17	.62	.00	48.0	0.0	100	0
8 (done)	.12 ³	.50	.07	28.5	17.3	59	36
10 (overdone)	.11	.52	.09	.....	.....	.....	.....
12 (overdone)	.12	.54	.11	.....	.....	.....	.....
14 (overdone)	.14	.60	.16	.....	.....	.....	.....

¹ Approximately four minutes were required to bring the water back to boiling after the frosted peas were added. ² The values for the cooked peas were computed on the wet weight of the cooked samples. ³ When calculated in terms of the uncooked peas this value is .10. ⁴ Change in vitamin content of water owing to evaporation and removal of samples as well as solution from the vegetable.

This slight destruction, even after holding, may be because the so-called ascorbic acid-oxidizing enzyme was inactivated during the blanching. At the end of the cooking period the peas taken directly from storage at —40°F. retained 59 per cent of their vitamin C while 36 per cent had been transferred to the cooking water; and the peas held in the refrigerator retained 56 per cent while 39 per cent had been transferred to the cooking water. At the end of a 16-minute cooking period fresh peas of the same variety retained 42 per cent of their vitamin C while 44 per cent had been transferred to the cooking water.

The vitamin C content of the cooked frozen peas, .12 mg. per gram, compares very favorably with that of the cooked fresh peas of the same variety, .11 mg. per gram, as reported by Fenton, Tressler, and King (1936). The cooking water of the frosted peas contained less vitamin C, .07 to .08 mg. per c.c., than did that of the fresh peas, .13 mg. per c.c. Both these differences may be partially explained by the fact that the frosted peas required only eight minutes and the fresh peas 16 minutes of cooking. It seems probable that, in general, cooked frosted peas compare very favorably with cooked fresh peas, particularly when the latter are purchased on the open market, for Mack, Tressler, and King (1936) found that fresh peas lose about one-half of their vitamin C content when held at room temperature for three days.

TABLE 3
Vitamin C Losses From Frosted Peas Stored Overnight (16 Hours) in a Refrigerator 4.4°C.(40°F.), and Gain to Cooking Water

Cooking period ¹	Ascorbic acid						
	Drained peas ²		In cooking water ⁴	Total in		Original in	
	Wet weight	Dry weight		Drained peas	Cooking water	Drained peas	Cooking water
	mg. per gm.	mg. per gm.	mg. per c.c.	mg.	mg.	pct.	pct.
min.							
0 (uncooked)	.17	.76	.00	.....	.....	.....	.....
3	.13	.48	.04	.....	.....	.....	.....
4	.12	.47	.05	.....	.....	.....	.....
5	.12	.47	.05	.....	.....	.....	.....
6	.11	.46	.06	.....	.....	.....	.....
7	.10	.46	.07	.....	.....	.....	.....
8 (done)	.10	.46	.08	.....	.....	.....	.....
No sampling until peas were done.							
0 (raw)	.17	.76	.00	48.0	0.0	100	0
8 (done)	.12 ³	.54	.08	27.0	18.7	56	39

¹ Approximately two and one-half minutes were required to bring the water back to boiling after frosted peas were added. ² The values for the cooked peas were computed on the wet weight of the cooked samples. ³ When calculated in terms of the uncooked frosted peas this value is .10. ⁴ Change in vitamin content of water owing to evaporation and removal of samples as well as solution from the vegetable.

Having the kettle covered or uncovered seemed to make no difference in the loss of vitamin C from the frosted peas as in both cases of eight minutes' cooking the decrease was from .15 to .11 mg. per gram. Having the water come back to boiling in two minutes or four minutes made no difference in results; in both cases the decrease was from .16 to .12 mg. per gram. The above findings may be partially explained on the basis that the so-called ascorbic acid-oxidizing enzyme is inactivated during the blanching and that most of the loss of the vitamin from the peas is to the cooking water. This transference would probably not be affected by the kettle being covered or uncovered or by the slightly longer time required for the water to

come to the boil, since in each case the peas were cooked for the same length of time.

SUMMARY

1. The vitamin C content of fresh peas of the Thomas Laxton variety was reduced from .25 to .18 mg. per gram wet weight or a loss of about 38 per cent during the processes, other than actual freezing, involved in putting the peas on the market in the frosted form (blanching 60 seconds in boiling water or 120 seconds in steam at 100°C.(212°F.)), cooling, packaging, sealing, and shipping.

2. The vitamin C content of frosted peas remained practically the same when they were taken directly from storage at -40°C . (-40°F .) and held (1) in an electric refrigerator at 4.4°C . (40°F .) for 16 hours or (2) at room temperature (80°F .) for one and five hours.

3. The cooked frosted peas, which were taken directly from storage at -40°C ., retained 59 per cent of their vitamin C and 36 per cent was dissolved in the cooking water. The cooked frosted peas which had been held in the refrigerator retained 56 per cent of their vitamin C, and 39 per cent was dissolved in the cooking water.

4. The vitamin C content of the cooked frosted peas studied was about the same (.12 mg. per gram) as the cooked fresh peas of the same variety (.11 mg. per gram) determined in a previous study.

5. The vitamin C content of the cooking water at the end of the cooking period was .07 to .08 mg. per cubic centimeter.

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LOSSES OF VITAMIN C DURING THE COOKING OF CERTAIN VEGETABLES¹



HE percentage of the total biologically active ascorbic acid actually destroyed during the cooking of vegetables has been uncertain. In animal studies reported by other workers in which the results naturally gave the total ascorbic acid, the cooking water was not taken into consideration, probably because it would be difficult to get animals to consume the large amounts of cooking water necessary. In most of the chemical studies reported by other investigators, no consideration was given to the dehydroascorbic acid which is also biologically active (1, 2).

The purpose of this paper is to summarize the results of 4 studies (3, 4, 5, 6) and to discuss them with particular reference to their home economics and public health significance. In these studies both the ascorbic and the dehydroascorbic acid in the raw and cooked vegetables and the cooking water were determined chemically and checked by biological assay.

Three classes of vegetables—leaf, root, and seed—were chosen. These vegetables, freshly harvested, were of known varieties and from a known source. Two varieties of Swiss chard (3), one variety of carrots (4), and two varieties of peas (5) were

chosen. In addition, one variety of frosted peas was studied (6).

Method. Vitamin C assays were made by the dichlorophenolindophenol method. The dehydroascorbic acid present was regenerated by the hydrogen sulfide method. The biological assays were made by the curative feeding test.

Each vegetable, whether fresh or frozen, was cooked by boiling; in addition, carrots were steamed because they lend themselves well to this method of cooking. The amounts of vegetables and cooking water and time of cooking are given in table 1.

Results. The titration values and percentage losses for the fresh vegetables are given in table 2. There was not much difference in the vitamin C content of the particular varieties of each vegetable studied. Since the stems of chard contained only about one fifth as much vitamin C as the leaves, it was necessary to take great care in sampling in order to obtain a representative sample.

As will be noted, very little actual destruction of vitamin C occurred during the boiling, perhaps because of the inactivation of the ascorbic acid oxidizing enzyme during the first few minutes of cooking. A large proportion of vitamin was found in the cooking water, which is not surprising considering the great solubility of vitamin C in water. The transfer of the vitamin to the cooking water was rapid during the first 2 or 3 minutes of cooking, but after

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that it was slow, as is shown by the data

were thin enough so that heat, which

for chard in table 3.

inactivates the ascorbic acid oxidizing

TABLE 1

Amounts of vegetables and water and time of cooking

VEGETABLE	VARIETY	WEIGHT OF		TIME OF COOKING
		Vegetable	Water	
		grams	grams	minutes
Chard	Lucullus	350.0	1200	10
	Fordhook	350.0	1200	10
Carrots	Chantenay	325.0	750	15
	Chantenay	325.0	—	20
Peas	Thomas Laxton	525.0	700	15
	Alderman	525.0	700	16
Frosted peas	Thomas Laxton	283.5	292	8
	Thomas Laxton	283.5	292	8

TABLE 2

Ascorbic acid in the chard, carrots, and peas (no interference from sampling)

VEGETABLE	VARIETY	CONDITION OF VEGETABLE	ASCORBIC ACID				
			Drained vegetable	Cooking water	Retained in vegetable	Loss in cooking water	Destroyed
			mg. per gram	mg. per gram	per cent	per cent	per cent
Chard	Lucullus	Raw	0.43	—	100	0	0
		Boiled	0.17	0.09	39	53	8
	Fordhook	Raw	0.36	—	100	0	0
		Boiled	0.14	0.06	40	45	15
Carrots	Chantenay	Raw	0.064	—	100	0	0
		Boiled	0.036	0.017	56	33	11
		Raw	0.055	—	100	0	0
		Steamed	0.050	—	86	—	14
Peas	Thomas Laxton	Raw	0.23	—	100	0	0
		Boiled	0.11	0.13	42	48	10
	Alderman	Raw	0.25	—	100	0	0
		Boiled	0.15	0.12	53	40	7

The steamed sliced carrots retained 86 per cent of their ascorbic acid content. The high retention of vitamin C in these carrots may be because the vegetable was not immersed in the water and $\frac{1}{8}$ inch slices

enzyme (7), could quickly penetrate to the center of the vegetable. Furthermore the holes in the inset pan of the steamer were in the rim and not in the bottom of the pan.

The results of the study of frosted peas

are given in table 4. It will be observed that the frosted peas lost 38 per cent of their

TABLE 3
Ascorbic acid in the cooking water of chard

LENGTH OF COOKING PERIOD	ORIGINAL VITAMIN C TRANSFERRED TO THE WATER
<i>minutes</i>	<i>per cent</i>
0 (raw)	0
2	25
4	39
6	48
8	51
10 (done)	53

vitamin C in the processes incident to putting them on the market in the frozen state. This loss, however, was not due to

vitamin C while standing at room temperature for 1 to 5 hours or while held in an electrical refrigerator at 40°F. overnight (16 hours), whether they had been blanched 60 seconds in boiling water or for 120 seconds in steam at 212°F. This is contrary to the findings of some other workers (10), who found a loss of 68.7 per cent when the peas were defrosted from 2 to 6 hours. The loss observed by these investigators may be due to the fact that they blanched the peas in steam for only 40 seconds. This may not have been long enough to inactivate the oxidizing enzymes. However, Jenkins, Tressler, and Fitzgerald (9) found that thawing did not cause much loss of the ascorbic acid content of

TABLE 4
Ascorbic acid in fresh, frozen, and thawed peas (Thomas Laxton variety)

MATERIAL	COOKING TIME	ASCORBIC ACID				
		Retained in drained peas		Found in cooking water		Destroyed
	<i>minutes</i>	<i>mg. per gram</i>	<i>per cent</i>	<i>mg. per cc.</i>	<i>per cent</i>	<i>per cent</i>
Fresh peas	0	0.23	100	0	0	—
Fresh peas	16	0.11	42	0.13	48	10
Frozen peas	0	0.17	100	0	0	—
Frozen peas	8	0.12	59	0.07	36	5
Thawed peas	0	0.17	100	0	0	—
Thawed peas	8	0.12	56	0.08	39	5

the freezing itself, for fresh, unblanched peas frozen for the biological assay showed no decrease in vitamin C content. Nor was any loss found during the feeding test when the frozen peas were held in dry ice (5). The vitamin C loss in the commercial pack must be attributable to washing, blanching, cooling in water, and other procedures (8) used in the quick freezing process. Jenkins, Tressler, and Fitzgerald (9) report a 30 per cent loss of vitamin C during the processing, 10 per cent of which occurred during blanching. They found that the most rapid loss occurred "during the cooling and washing operations subsequent to blanching."

These peas did not show any loss of

peas. Apparently the blanching methods used in their study as well as those used in this study are efficient in inactivating the ascorbic acid oxidizing enzyme. However, holding frozen peas is not advisable because spoilage may occur.

The cooked frosted peas contained just as much vitamin C as the cooked fresh peas (0.11 to 0.12 mg. per gram). This may be because the fresh peas were cooked twice as long (15 to 16 minutes) as the frozen peas (8 minutes), and because the ascorbic acid oxidizing enzyme was inactivated during the blanching of the frosted peas. In view of the findings of Mack, Tressler, and King (11) that fresh peas lose 50 per cent of their vitamin C when

allowed to stand at room temperature for 3 days, it is possible that frosted peas may be a better source of vitamin C than fresh peas purchased on the open market.

The titration values were confirmed by bio-assays on two varieties of the raw and cooked chard and peas and on one variety of the raw and cooked carrots. The lots of raw and cooked vegetables were frozen in a Birdseye Multiplate Freezer and stored in dry ice during the feeding period. Since the results of the biological assay closely paralleled those of chemical titration of the fresh peas and since freezing itself had no effect, it was not deemed necessary to make biological assays of the vitamin C content of the frosted peas.

Summary. The total vitamin C content of several fresh vegetables and one frosted vegetable has been determined before and after cooking. Very little vitamin C, 5 to 15 per cent, was actually destroyed; but a large amount, 33 to 53 per cent, was found in the cooking water. The solution of the vitamin in the cooking water was greatest during the first 2 minutes of cooking, as was also the actual destruction of the vitamin. The cooked chard, peas, and frosted peas contained about the same amount of vitamin C. The frosted peas lost about 38 per cent of their vitamin C during the commercial processes, other than actual freezing, involved in putting them on the market. The cooked frosted peas were as good a source of vitamin C as were the cooked fresh peas.

Significance of the results. The results of experimental work indicate that there is need for additional investigation to determine the effect on the vitamin C retention of the possible variants in cooking. Heretofore in many of the published papers emphasis has been placed on chemical methods of determining the vitamin C content of the cooked vegetables and little or no emphasis on the details of the method of cooking. The studies herein summarized

indicate that methods of cooking are extremely important if the results of the investigation are to be duplicated in other laboratories. The details in the cooking method which probably play an important part in the retention of vitamin C are the cut surface area, the size of the pieces, the amount of water used, the time it takes the water to come back to the boil after the vegetable is added, and the total cooking time.

Since vitamin C is very soluble in water, an increase in the amount of cut surface exposed to the water would be likely to increase the vitamin C loss. The smaller the pieces, the less time it would probably take for the heat to penetrate and thus inactivate the ascorbic acid oxidizing enzyme. The effect of small pieces would probably be more favorable in steaming than in boiling because in steaming, the vegetable is not submerged in water.

Since so much of the vitamin has been found in the cooking water, one of the first questions which arises is whether there would be an increase in retention of the vitamin by the vegetable if no water were present. In boiling this would mean cooking the vegetable in such a small amount of water that at the end of the cooking period there would be none left. This question can be answered only by experimental results. It may be that there would be greater loss during the first few minutes of cooking, since the same amount of vegetables would cool off a small amount of water to a greater degree than a larger amount of water and consequently a longer period of time would be necessary to bring the water back to the boil and to give an atmosphere of steam above the vegetable. Perhaps also this method would require a longer period of cooking. When any vegetable is cooked dry there is always some material clinging to the sides and bottom of the pan. It is possible that some of the vitamin would be lost in this way. Fur-

thermore, the management element should not be lost sight of, since it is during the last few minutes before a meal is served that there are so many details demanding a housewife's attention. The margin of time between a vegetable cooked dry and a burned one is not very great. The optimum amount of water for the retention of vitamin C in each vegetable during boiling has not been determined. A study of the losses of vitamin C from vegetables cooked in a waterless cooker would be of interest.

No report has been found in the literature on the vitamin C content of the liquid which seeps out of many drained vegetables after they have been seasoned with butter, salt, and pepper.

Further investigation is needed on the effect of the length of time required to bring the water back to the boil after the vegetable is added.

Since vitamin C is so soluble in water, it would seem at first thought that steaming would give smaller losses of vitamin C than boiling. This was found to be true in the case of carrots where the pieces were small so that it was possible for the heat to penetrate them quickly and where the holes were in the rim and not in the bottom of the upper inset pan. The latter type of steamer might allow "leaching out" of the vitamin. Further work might well be done on the effect of the length of time of cooking. More determinations might also be made with other methods of cooking, such as deep-fat frying and pan frying. In drawing any conclusions care should be taken that no generalizations are made from one kind of vegetable to another, as each vegetable may be "a law unto itself."

Since the stems of Swiss chard and spinach have been found to be much less potent in vitamin C than the leaves and since the stems require a longer cooking period, it might be wise to put the stems on to cook a few minutes before the leaves or to use the

stems for soup or some other purpose, or even not to use the stems at all.

Another important factor, especially from the public health point of view, is that if these boiled vegetables are to retain their place as important sources of vitamin C in the American dietary, the home economist has a definite responsibility in teaching ways and means of utilizing the cooking water.

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